EXPLORATION SPACE SUIT ARCHITECTURE AND CRITICAL SCIENCE OPERATIONS FOR MARS

Presented to the Workshop on Planetary Protection Knowledge Gaps for Human Extraterrestrial Missions

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Questions Addressed

- What is geology?
- How do you do field geology?
- Why is it a critical science operation?
- Why can't robots just do the geology?
- What does a planetary walking suit look like?
- Can suited astronauts do geology?
- From where and how much does the suit leak?

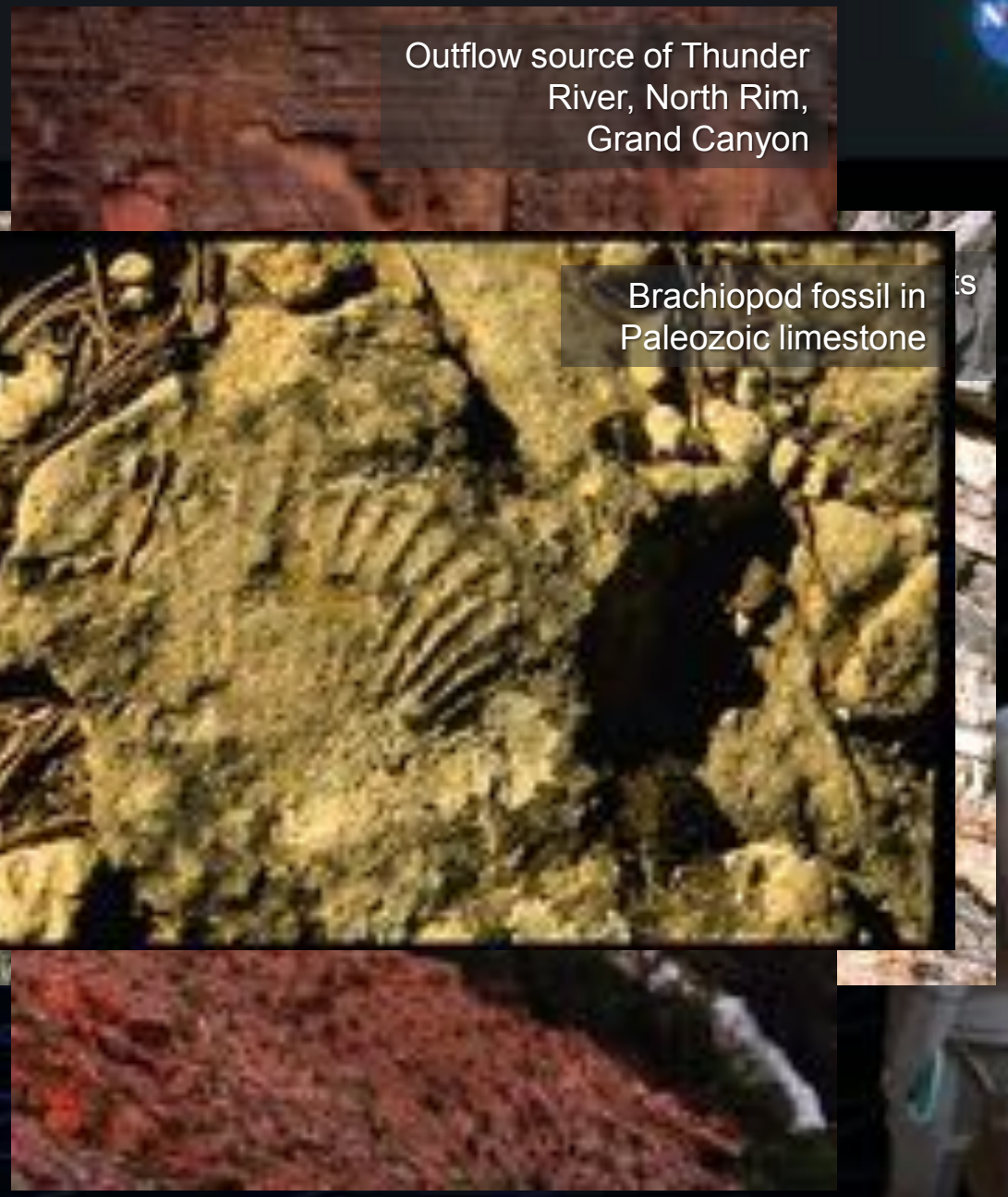
What Geology Isn't

- First, some misconceptions we have to deal with up front:
  - Collecting samples is doing field geology
  - Sample analysis is the most important part of doing geology
  - Geologists go in the field solely to make quantitative measurements on rocks
  - Field geologists work on measurement precision scales of millimeters or less
  - When a geologist goes into the field, they know exactly where to go and what they are going to find
  - Chemical composition data is the most important piece of information in the conduct of geologic investigations
- Remote sensing data will define the geology of planetary surfaces unambiguously, making geologic field work unnecessary

Each of these statements is wrong

What Geology Is

- Geologic field work can be loosely defined as the body of work necessary to:
  - Determine the spatial distribution, age and attitude of the rock types within an area
  - Document those structures that have deformed or cut those units
  - Determine the processes that led to the emplacement of these rocks, and have subsequently modified them

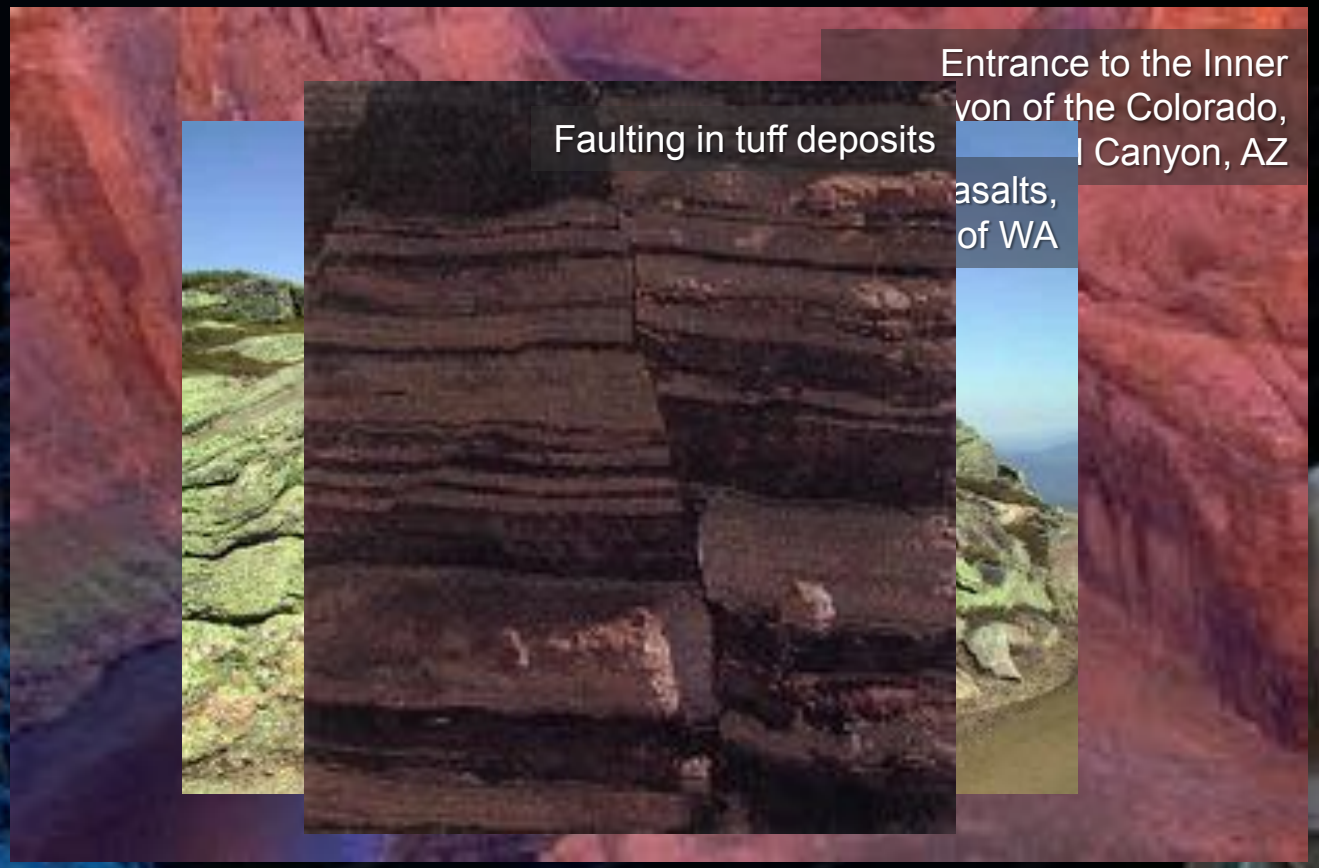


Outflow source of Thunder River, North Rim, Grand Canyon

Brachiopod fossil in Paleozoic limestone

Geology Is…

- Geologists collect a variety of data in the field, but it starts with:
  - The spatial distribution and geometric attitude of the rocks in the field
  - Geologists collect a variety of data in the field, but it starts with
    - The structures and the forces that deform them
    - The structures and forces that break them

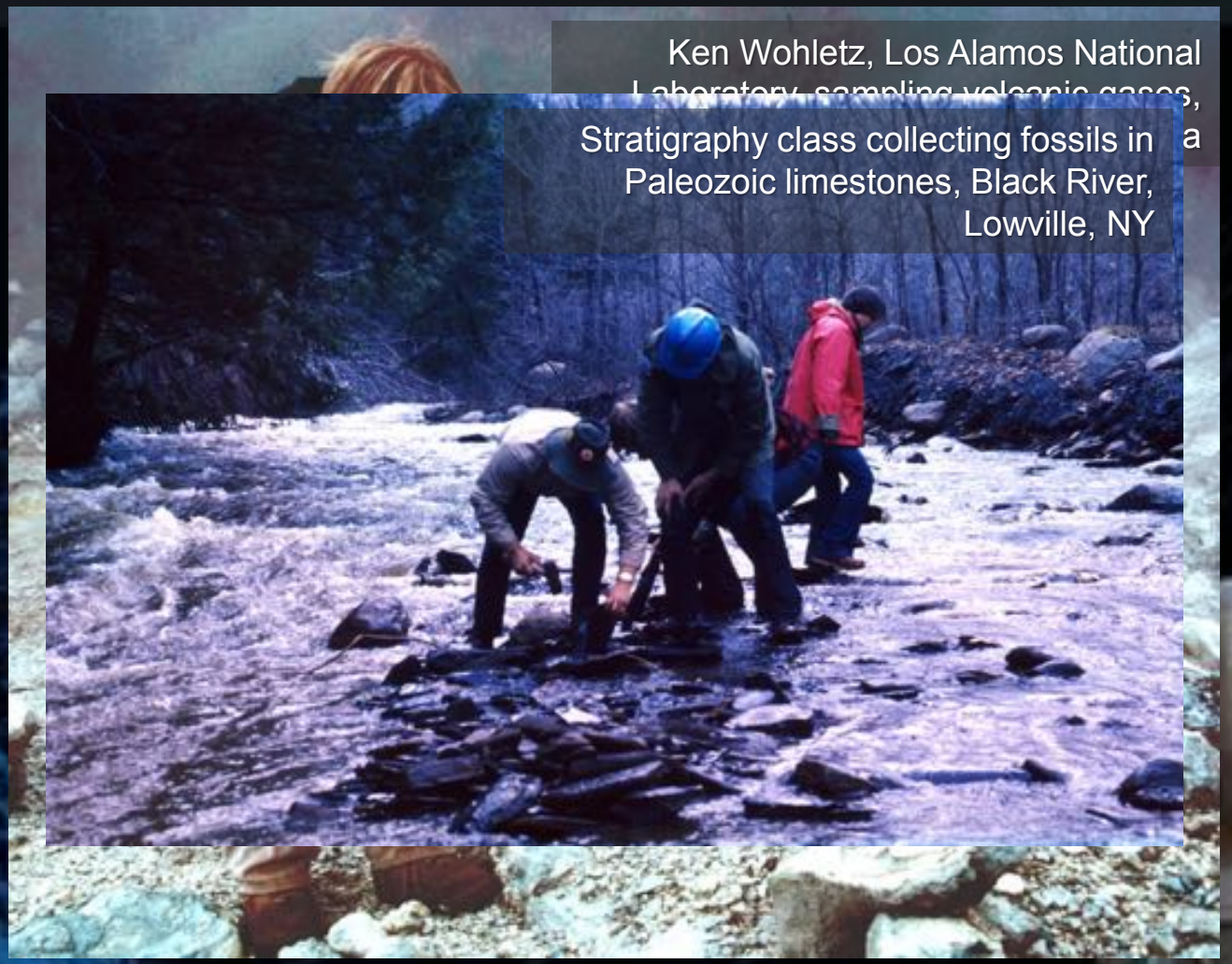


Sample Collection

- An important of doing field geology, but it augments the understanding achieved by field observations.
- Without that field context, you cannot interpret geochemical or geophysical data.
- Simply sampling local rocks without the geologic context is not sufficient.

"Engineers think, because geologists carry backpacks, all we do is collect rock samples. This is wrong - sampling is a very small part of what we do. Geologists carry backpacks to carry the beer…"

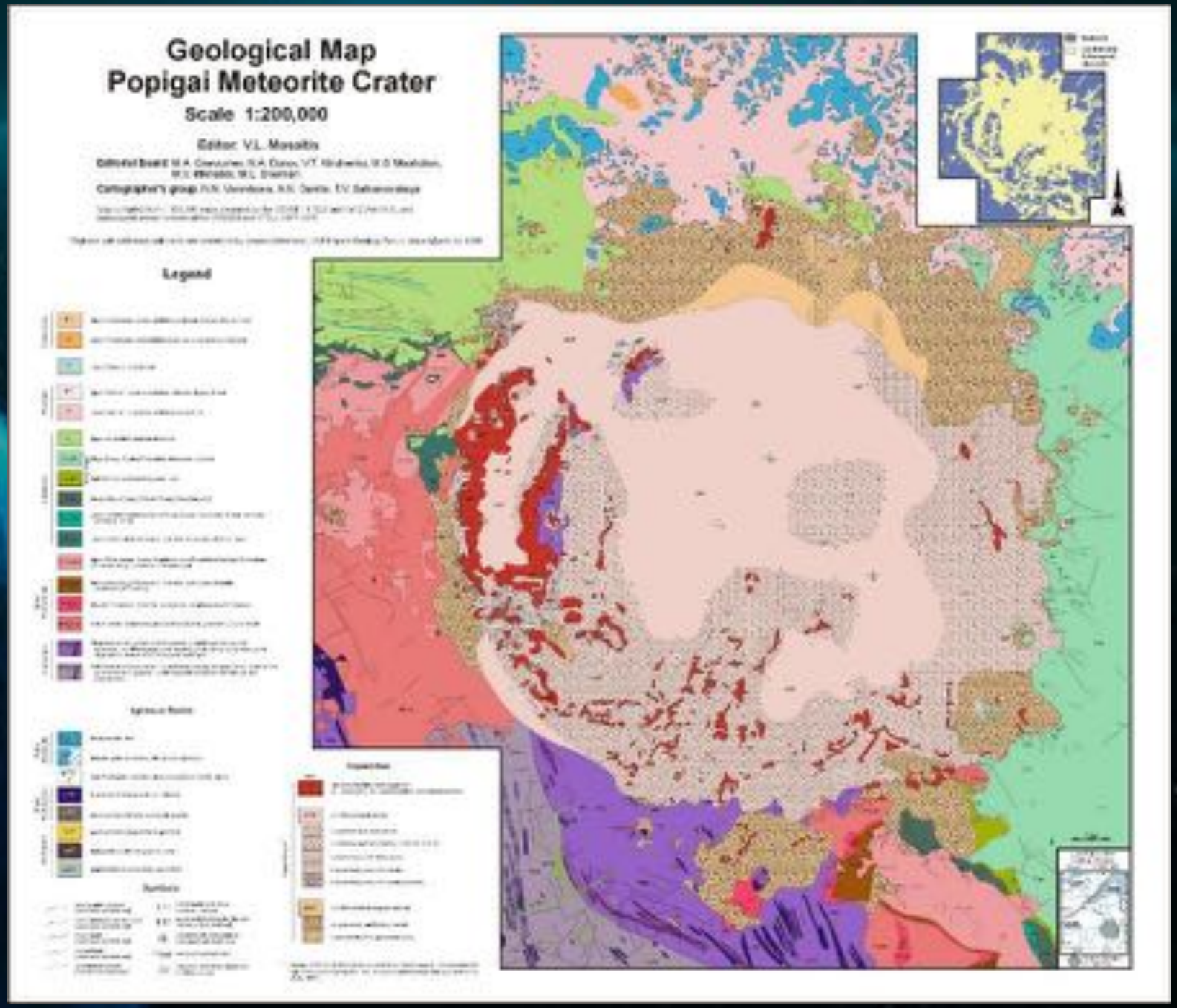
Jeff Taylor, LPSC Talk, 1990



Ken Wohletz, Los Alamos National Laboratory, sampling volcanic gases, a

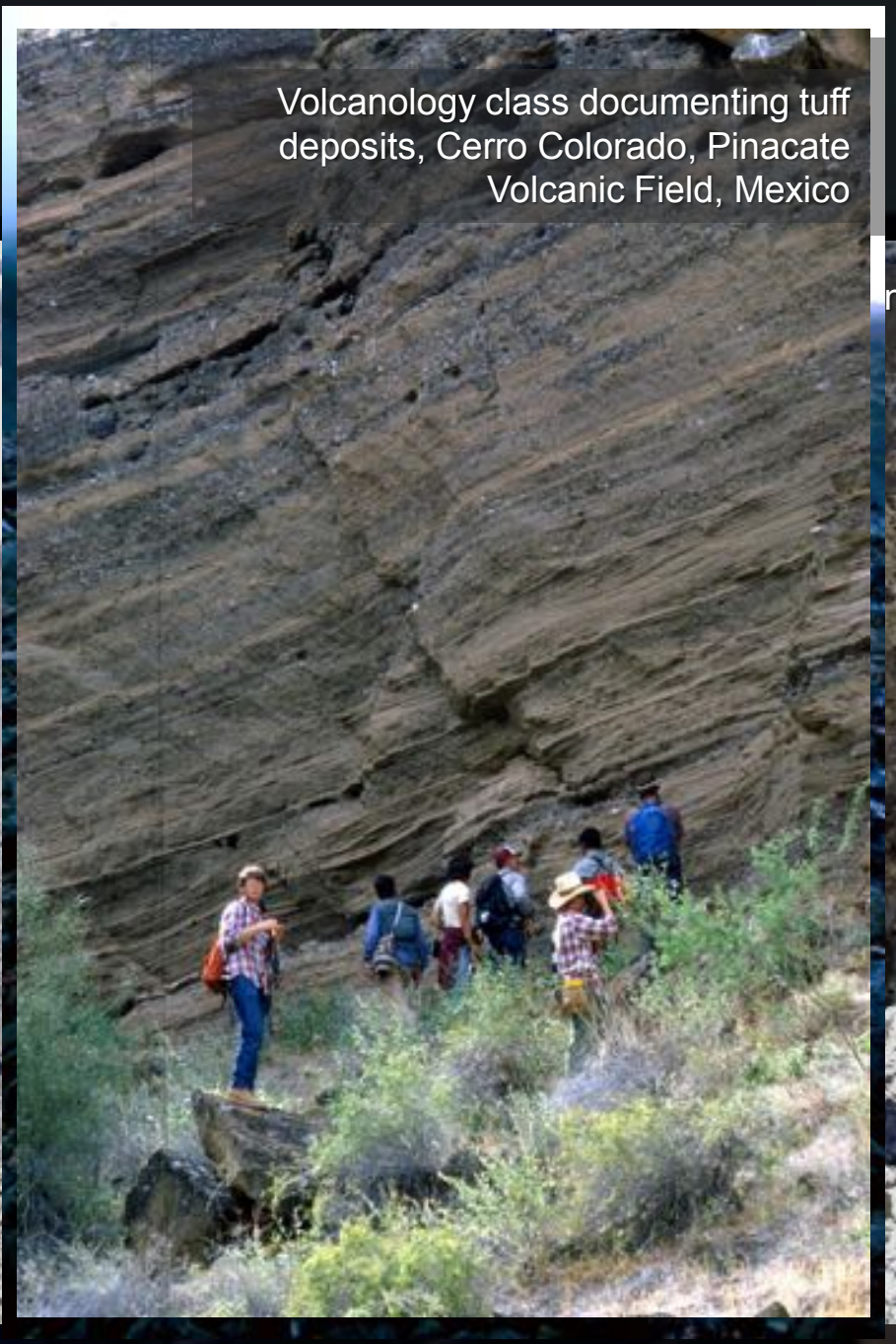
Stratigraphy class collecting fossils in Paleozoic limestones, Black River, Lowville, NY

This allows development of a geologic map, which is the first order output from geologic field studies and the basic tool for understanding geologic problems.

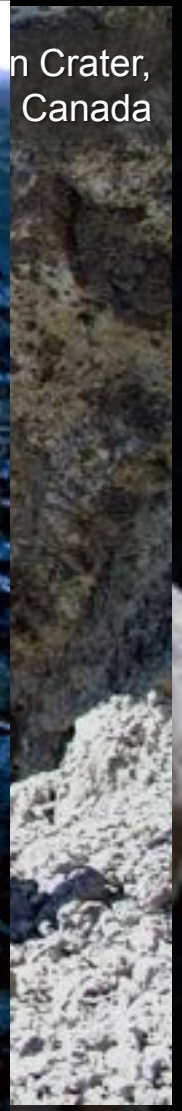


OK, So How Do You Do This?

- **First**, you have to get into the terrain, and know where we are on a geographically-based data base. You can not do geology solely from the inside of either a pickup truck or a pressurized rover.
- **Second**, you have to get up close and personal to the rocks, to get the micro-scale as well as the macro-scale picture.
- Geologists have to deal with substantive variations in scale in the field, ranging from looking at mineral grains <0.1 mm in size to rock units and structures that may be hundreds to thousands of meters in size, sometimes in the same outcrop.

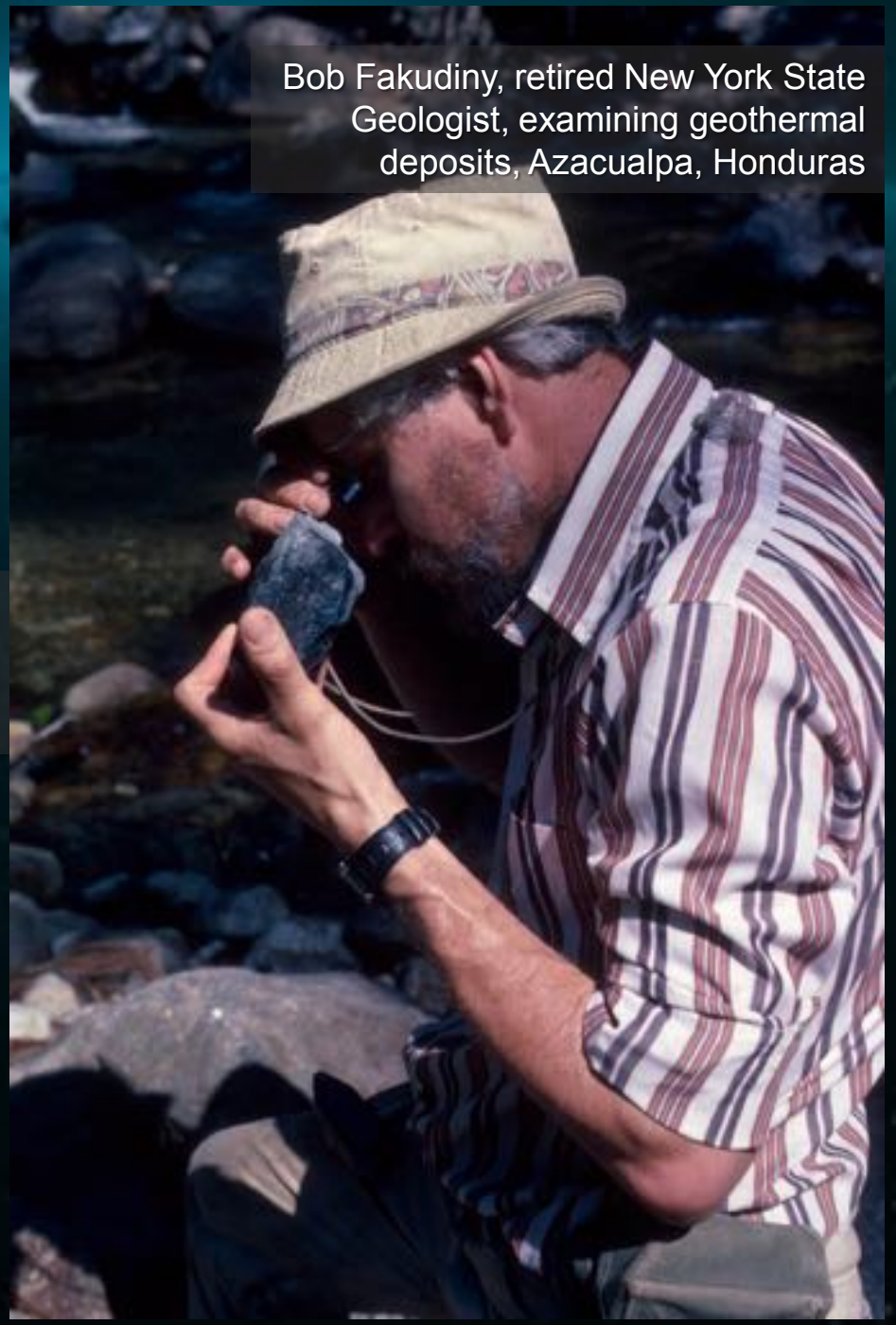


Volcanology class documenting tuff deposits, Cerro Colorado, Pinacate Volcanic Field, Mexico



n Crater, Canada

This includes having the capability to look at rocks at a resolution above that of normal human vision



Bob Fakudiny, retired New York State Geologist, examining geothermal deposits, Azacualpa, Honduras

OK, So How Do You Do This?

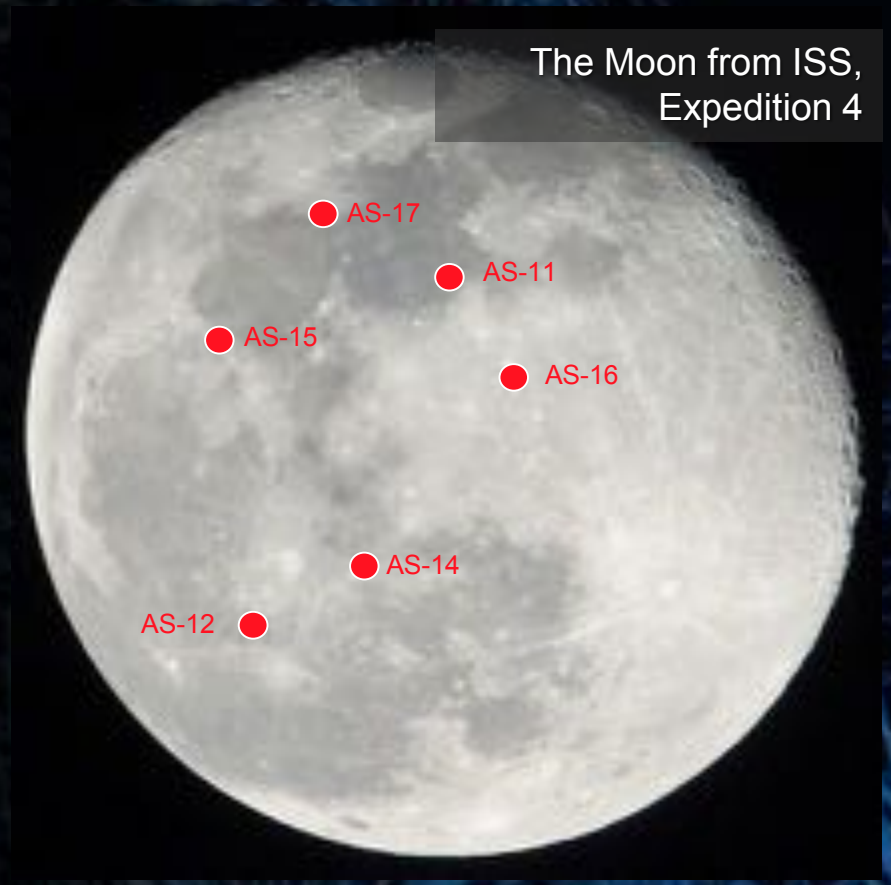
- **Third**, you have to be able to observe and describe, in detail, what you are seeing in the outcrop, and you have to be able to record that data in some fashion.

- Note taking is absolutely critical in geology; field notes are the primary data set, along with the notations on maps and air photos.

Steve Bolivar, Los Alamos National Laboratory, documenting field observations, Sambo Creek hot springs, San Pedro Sula, Honduras

Why Geology is a Critical Science Operation

The Legacy from Apollo's Geologic Investigation of the Moon



- The Apollo Program landed six missions on the lunar surface
  - All the landing sites were on the front side, largely in the equatorial region
- Everything we knew about the Moon prior to Apollo is pretty much what you see in this picture: an indistinct globe with a largely light colored surface, interspersed with patches of darker material and lots of holes in the ground

The Legacy from Apollo's Geologic Investigation of the Moon

- Prior to Apollo, most scientists thought that the Moon was a simple body composed of debris that was passively accumulated …it was not assumed to have any geologic processes of note, although there was much controversy about whether lunar craters were formed by volcanic or impact processes. In short, the assumption was that this body was accumulated under generally quiescent processes about 4.5 billion years ago, after which nothing happened except the occasional surface explosion.

- Apollo showed us that the formation of the Moon and, by inference, the Earth, was extremely violent, involving whacking Mars- and Earth-size planets together, the creation of huge impact basins (1000s of km across), the melting of the planet to a depth of several hundred kilometers (!), and the eruption of significant volumes of basaltic lava.

- As we have sent spacecraft throughout the Solar System since Apollo, we have learned that the story of the Moon is the story of the Solar System…the place we first learned that story was on the Moon, with geologic discoveries that came from

Earthrise, Apollo 10

Why Humans?

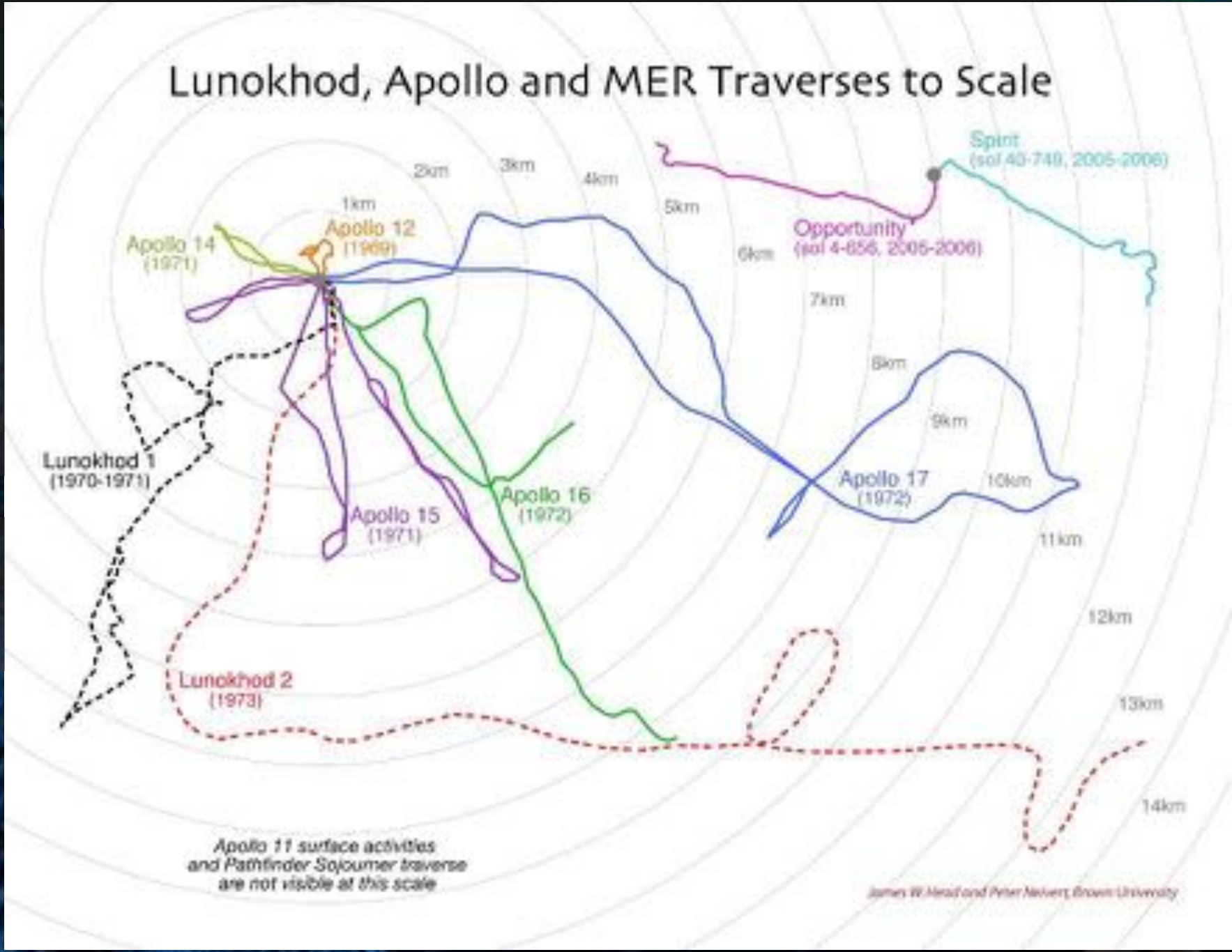
To compare statistics:

At the end of 3,042 days on Mars, the Opportunity Rover had driven:

21.4 miles

At the end of 3 days on the Moon, the Apollo 17 crew had driven:

21.6 miles



Basics: Why Do You Need an EVA Suit?

Space Suits Provide 3 Basic Functions For EVA Astronauts:

1 **First, in conjunction with a portable life support system, the space suit maintains the physiological well-being of the astronaut**

- Supplying oxygen for pressurization, breathing, and ventilation
- Provide carbon dioxide and metabolic heat removal

2 **Secondly, the space suit incorporates various mobility joint systems to enable the astronaut to perform EVA tasks in the pressurized condition**

- Includes both dual-axis and single axis joints and bearings

3 **Finally, the space suit provides protection against the hazards of the particular EVA environment**

- Thermal extremes
- Meteoroid and orbital debris
- Radiation conditions
- Abrasion and sharp edges
- Sand, dust, and rocks

In essence, the space suit is a small spacecraft in itself

What Does a Planetary Walking Suit Look Like?

- A space suit consists of two main components: a pressure garment that covers your body and a life support system that can be worn on your back
- Pressure garments are what we typically think of as a “space suit”, while the PLSS is that ill-defined box nobody pays much attention to…except, of course, if you’re in the pressure garment…

What Does a Planetary Walking Suit Look Like?

- Rear-entry
- Helmet angled and shaped for wide field view, including downward visibility
- Hard or soft torso, briefs and hip
- Waist bearing and flexion/extension joints
- Hip mobility joint system with 2 or more bearings and features for adduction/abduction
- Softgood arms and knees
- Walking boots with an ankle flexion/extension joint and ankle bearing
- Environmental protection garment that addresses dust,
  - Durability with UV radiation exposure, thermal protection in a
  - Low atmospheric pressure,
  - Durability with exposure to products of chemical reactions
- Could include a suitport interface plate (SIP)

What Does a Planetary Walking Suit Look Like?

Can Suited Astronauts Do Geology?

The capability has been demonstrated in remote field testing operations.

Suits will be flexible and rugged enough to bend over, dig holes, walk up hill to the outcrop, bash rocks, collect and stash samples, and look closely at rock specimens.

Suited Subjects Performing Geology Tasks